Invariant manifolds and the asymmetry of the Large Magellanic Cloud

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Abstract

The recent data provided by Gaia DDR3 has furnished precise information regarding the position and velocity of stars within the Milky Way and its surrounding areas. Using this refined catalog, the stars belonging to the Large Magellanic Cloud (LMC) have been identified, together with their sky position (azimuth and declination) and velocity.

The LMC is a barred galaxy that displays asymmetry in density within its central region, and also between its arms, which transport matter from the core of the galaxy to its periphery. In a previous study, we employed combinatorial and topological data analysis techniques on available star information to identify the main features of the LMC, such as its central bar, pattern speed, density distribution and arms.

In the present work, we apply these features to construct a potential modelling that of the LMC, and analyze the equations of motion of this model. Specifically, we investigate the asymmetry in the galactic arms produced by the inhomogeneity of the bar, as well as the effect caused by shifting the center of mass of the system away from the main axis of the bar. To achieve this, we examine the invariant manifolds associated to the Lyapunov periodic orbits around the unstable equilibrium points located at each end of the galactic bar. As previously established, these invariant manifolds outline the arms and rings of barred galaxies, carrying matter between the interior and exterior parts of the galaxy.

The orbits trapped inside these manifolds are actually responsible for transporting matter through the Lyapunov periodic orbits around the equilibrium points, which serve as gateways between the regions of the galaxy delimited by the zero velocity curves. Material from the core of the galaxy moves along these manifolds towards the periphery, forming the spiral arms originating from the ends of the bar. If the mass distribution within the center of the galaxy is uneven, as a result of an asymmetric bar or a non-centered bulge, the dynamics around the two unstable equilibrium points at the ends of the bar become asymmetrical. One of the invariant manifolds expands, enveloping a smaller area and resulting in fewer escaping orbits that are spread over a wider region. This leads to a weaker and more disorganized arm in comparison to the one at the opposite end of the bar. A similar effect occurs when the center of mass of the system is displaced from the bar main axis, causing a change in the dynamics of one of the triangular points, which was stable in the case of a perfectly symmetric system.

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